DETECTING FIDUCIAL POINTS IN PHYSIOLOGICAL SIGNALS

FIELD

Various aspects of the present disclosure relate to the processing of physiological signals, and more particular aspects relate to detection of fiducial points in quasi-periodic signals, such as identifying QRS complexes in an ECG.

BACKGROUND

Implantable and external devices are used to monitor physiologic signals of human and animal subjects. These devices may incorporate various types of sensors and can measure and record signals from those sensors for processing by a system or monitoring center located remote from the subject, or in other cases, the device may perform some or all of the desired signal processing to extract information from the measured signals and forward the resulting information to a remote system for display, recording, or further processing.

The signal processing is performed to extract information from the signal in order to assess the physiological condition of the monitored subject and often to evaluate the response of the subject to a therapy or experimental protocol. Examples of quasi-periodic physiological signals include respiration, ECG, blood pressure, blood flow, and photoplethysmography measurements of blood gases. Clinicians can use this information to make therapy decisions and researchers can use this information to assess the safety and utility of experimental therapies. This information may also be used for closed loop control of therapy delivery. In other examples, measurements of peripheral nerve activity (PNA), respiration, blood oxygen, blood glucose, EEG, EMG, heart sounds and blood flow signals are processed to extract information for clinical or research purposes.

There is an increasing reliance on automatic processing to extract information in order to reduce labor and costs and to more consistently and accurately evaluate the physiologic condition of the subject. In therapeutic devices automatic detection of fiducial points, such as the QRS complex of an ECG, is often useful for feedback control. Accurate QRS detection in ECGs is also the foundation for identifying arrhythmias and measuring intervals in ECGs recorded for research or diagnostic purposes. However, highly accurate QRS detection is often compromised when the ECG contains significant levels of in-band noise (e.g., ambulatory ECG recordings). This often results in high rates of false positive and false negative detection of arrhythmias mandating manual (e.g., human operator) over-read of the signals following processing by an algorithm.

In some physiologic signal processing applications, automated analysis is complicated by the fact that measured signals are the result of activity of multiple sources, referred to as multi-source signals. An example of a multi-source signal is ECG measured on the surface of the body where electrical activity is sensed from the atria and ventricles as well as skeletal muscles. It is useful, for example, to observe atrial activity independent of ventricular activity in order to improve the detection of atrial arrhythmias. Current techniques for providing signal source extraction of multi-source signals, such as independent component analysis (ICA), assume independence of sources and performance is compromised when this assumption in invalid, such as is the case when separating atrial and ventricular activity in an ECG. In addition, ECGs are often recorded from ambulatory subjects using a small number of sensing leads, further complicating

signal source extraction and fiducial point detection (e.g., atrial activity detection) due to the mixing of sources inherent in a small number of leads.

Other signals, such as peripheral nerve activity (PNA) and brainstem auditory response, have proven difficult to analyze because of very low signal-to-noise ratio (SNR). Visual analysis of these signals is often inadequate to detect important features and obtain a quantitative evaluation.

Many physiological signal processing techniques have been difficult to successfully implement under certain conditions, particularly when processing signals from ambulatory subjects where the signals are often quite noisy. For example, measurements of ECG parameters such as heart rate, QT interval, and PR interval may contain errors due to inaccurate QRS detection. When noise is present due to patient movement or when there is background acoustical noise (e.g., when the patient is being transported in a helicopter, ambulance, or automobile), measurements of blood pressure obtained from an arm cuff may contain errors as a result of inaccurate detection of the changes in acoustical sounds or other measurements that correlate with systole or diastole. Detection of ventricular and atrial arrhythmias in ECG may have excessive incidence of false positives due to the inability of a signal processing algorithm to provide accurate detection, particularly in the presence of noise. Because of lack of confidence in the accuracy of results, human review has often been used to confirm results or correct errors made by automated analysis algorithms.

Inaccuracies in performance can also result in excess telecom costs when monitoring ambulatory subjects. For example, some types of ambulatory ECG monitoring devices employ on-board signal processing to detect arrhythmias and forward the detected arrhythmias to a monitoring center where they are further processed and reviewed by a human being using a data review system. Because of limitations in existing algorithms, there is a high rate of false positive arrhythmia detections in the ambulatory device that results in a high volume of data transmitted from the patient to a monitoring center. These aspects can result in excessive telecommunications expense, the need for additional memory in the ambulatory monitoring device, and additional expense to manually review the data received at the monitoring center.

Data compression is often used to reduce the volume of data needed for storage or transmission. Various methods of ECG data compression are limited in their ability to provide high levels of compression with minimal signal distortion in part due to the presence of noise that hinders accurate QRS detection. Accurate QRS detection can facilitate the use of more efficient data compression techniques that can reduce the volume of data that must be stored in memory on an ambulatory monitoring device as well as reduce the volume of data transmitted from the monitored subject. In certain applications, this can result in a reduction in telecom expense and a reduction in power consumption in the ambulatory monitoring device, leading to a reduction in the device size and extension of battery life.

The presence of noise in physiological signals and its negative impact on accurate fiducial point detection can be a limiting factor in providing accurate and consistent computerized evaluations and extraction of information. The noise is especially problematic when its frequency content falls within the bandwidth of the signals of interest (referred to as in-band noise). For example atrial signals can be contaminated by electrical activity of the ventricle, and ECG signals can be contaminated by EMG from the skeletal muscles. The plethora of signal sources contained within a limited number of channels measured in a surface ECG, with each channel